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acus. The typical and largest species, *C. pelvidens* Cope, is from the Puerco Eocene of New Mexico; the smallest species, *C. angulatus* Cope, is from the Wasatch beds of New Mexico and Wyoming (Fig. 14). Perhaps it is near this genus that Tricentes Cope, should be placed. The latter only differs from Chriacus in the possession of but three superior premolars.[1] I have suspected that it belongs near Microsyops and Mixodectes in the Lemuroid series. There are three species, none larger than a skunk. The type, *T. crassicollidens,* is known from parts of two crania. The *T. inæquidens* was not larger than a gray squirrel.

The *Deltatherium fundaminis* Cope (Fig. 20), is one-half larger than the Virginian opossum, and much more robust. Its molar teeth are very opossum-like, while its canine teeth are relatively larger and stouter. The crowns of the canines are especially effective as weapons, from their vertical direction and form, their sharp anterior and posterior cutting edges, and their sides grooved like many blood-letting instruments. The sagittal crest is high, and the muzzle is short and wide, so that a decidedly bull-dog expression belonged to this animal. It is the most specialized form of the family and of the Puerco epoch, and was one of the most abundant. There are two other less known species of Deltatherium.

(To be continued.)

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ANATOMY AND PHYSIOLOGY OF THE FAMILY NEPIDÆ.

BY WILLIAM A. LOCY.

(Continued from page 255.)

The Salivary Glands.—The most anterior appendages to the alimentary canal are the salivary glands. These are especially well developed in the Hemiptera, and secrete a juice which doubtless aids in the digestion of food. The Nepidæ have four glands in two pairs, each pair consisting of a small gland and a large one, which open by ducts near the commencement of the œsophagus. The large glands, which are about five times the length of the small ones, extend back to the first abdominal segment, and are there united to the stomach by threads of tracheæ. At the anterior ends of the large glands are two round pouches, which probably serve for the storage of small quantities of saliva.

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[1] See Proceeds. American Philosoph. Society, 1883, p. 315.

Connected with the salivary system, but separate from the glands, are two sigmoid pouches, called salivary reservoirs, which are supposed to serve for storing larger quantities of saliva. These are applied to each side of the stomach, at its commencement, and are continued backwards by a tubular appendage, which ends blindly in the first abdominal segment, being there attached to the stomach and to the large salivary gland by tracheary threads. The ducts of the reservoirs are kept open by a transversely striated ribbon, coiled in a spiral manner, and thus are similar to the tracheæ in structure.

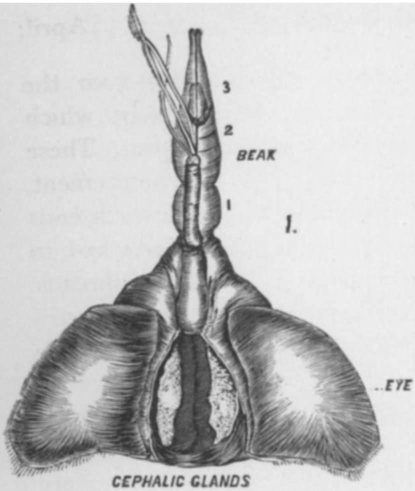
The salivary glands are conglomerated and, therefore, of high order. The globules are closely packed, sessile, and situated upon tubules, which join with others of like origin, and empty their contents into a common duct.

Comparatively speaking, the glands in Ranatra are not as long as those of Belostoma, and the salivary pouches, at the front end, are lacking. The salivary reservoirs are lenticular, and their cæcal appendages are longer than in Belostoma.

The Malpighian Tubules.—The Malpighian tubules, so named from their discoverer, Malpighi, are appended to the intestine. They consist of two tubules, of small and uniform size, united by four insertions to the bulbous enlargement of the intestine; each insertion is mediate, *i. e.*, connected with a pouch which opens into the intestinal bulb. These tubes are much convoluted and matted about the bulb, and are closely applied over the intestine, extending also over the stomach and into the fat body. On account of the difficulty with which they are unrolled, no exact measurements of their length has been made. I should judge, however, that they are about six or eight times the length of the body.

They have been indifferently called biliary or hepatic tubules, on account of their supposed function; but the discovery of uric acid and other urinary products in their secretions, indicates for them a urinary function. It is possible, that in some cases they unite with this urinary function the secretion of a sort of bile. The opinions of anatomists of the past half century regarding their function are various. By Cuvier, Dufour and Carus, their function was believed to be biliary, and by Strauss-Dürckheim and other anatomists urinary. These contrary opinions were, in a measure, reconciled by the views of Lacordaire, who believed their function

PLATE IX.



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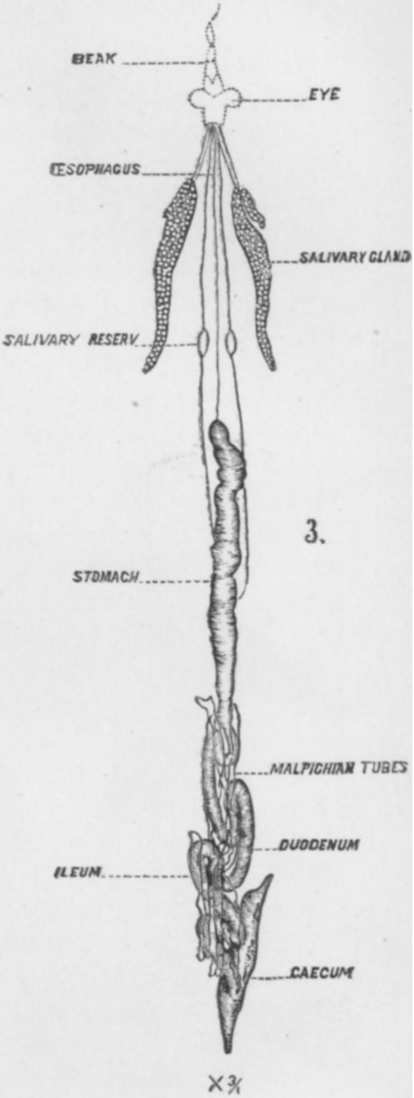

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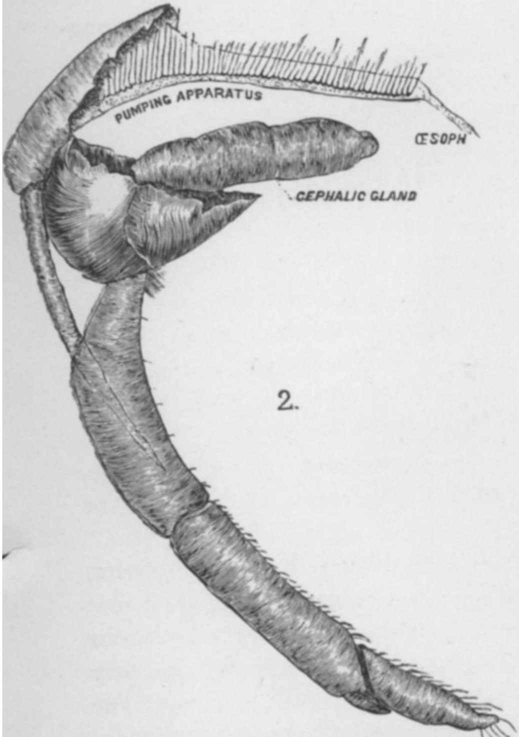

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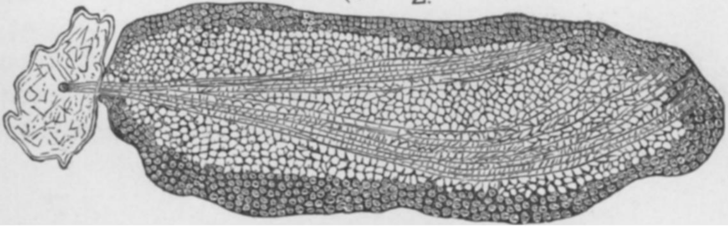

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to differ according to position on the alimentary canal, of which, in the Insecta, there are three—on the stomach, biliary alone; on the post-ventriculus, urino-biliary; at the extremity of the alimentary canal, urinary alone. According to this view they would be urino-biliary in the Nepidæ. I am not prepared to speak concerning their function, as I have made no analysis of their secretions.

The Fat Body.—The internal organs are entirely enveloped in a fatty tissue, called the fat body, which divides the heart and the nervous system from the other organs of the body. It is composed of connective tissue holding in its meshes globules of fat. This fat body is always a serious encumbrance in tracing the respiratory system, and it also obscures other internal organs. The fat may be dissolved in sulphuric ether, after which the branching of the tracheæ may be studied. This tissue is most strongly developed in the abdomen, and in the Nepidæ I have noticed that it is thickest in the fall, and becomes thinner when the insect is deprived of food; it is probably, therefore, a storehouse of nourishment, and may also serve as a protection to the internal organs.

The Odoriferous Glands.—In Belostoma, the odoriferous glands are two cæcal pouches situated in the metathorax, under the commencement of the stomach. They are convoluted several times upon themselves, and the distal and anterior ends are close together, both concealed under the nervous cord; the external opening is between ths coxæ of the posterior legs. When extended, they will reach to about the fifth abdominal segment. The smell emitted by these glands is pleasant, resembling that of well ripened pears or bananas.

The Glands of the Head.—In the genera, Belostoma, Perthostoma and Ranatra, I have observed two glands within the head, similar in position to the green glands of the Crustacea, which I shall provisionally name the *cephalic glands*, since they are not mentioned in any authority to which I have access. (Plate IX, figs. 1, 2 and 2*a*.) They are on the floor of the head cavity beneath all the other organs, and therefore are most easily approached from beneath. Their external openings are on each side of the head, between the eyes and the base of the beak. The ducts are short, and seem to be composed of a number of united ducts, which originate in individual cells. Under the microscope these glands show a thin homogeneous enveloping layer, and an epithelial layer composed of five-sided cells, each containing a prominent central nucleus. In some cases two nuclei are present. When these insects are irritated, a secretion is freely thrown out around the base of the beak, which produces death very quickly when introduced on a needle point into the body of an insect. The "cephalic glands" may be the source of this poisonous secretion; on the other hand their function may be entirely different; this question may be decided by the chemical analysis of the secretion of these glands, that is now being made in the University of Michigan.

II. THE CIRCULATORY SYSTEM.

After the food is reduced to chyle in the alimentary canal, it passes by osmosis through the walls of the intestines into the general circulation; it is conveyed in this way to various parts of the body, and converted into tissue. The circulation of the blood and the structure of the heart in insects is considered one of the most difficult points in their physiology, on account of the delicacy of the structure involved, and the confusion that has arisen among authorities from the absence of true arteries and veins. So much interest and importance is attached to this subject, that I give below a brief history of it.

About the middle of the seventeenth century Swammerdam and Malpighi, each independently, discovered in the larvæ of certain insects a rhythmically contracting vessel lying along the back, which they considered a heart. In the course of time Lyonet threw some doubt upon this conclusion in his memorable work on the larva of *Cossus ligniperda*. This doubt was increased by Cuvier, who, after a special study of circulation in insects, gave as his opinion that no such thing as a regular circulation existed in this class of animals. Thus naturalists came to believe that insects had no circulation.

In the early part of the present century, however, Carus made the true discovery of the circulation of blood in the Insecta, and his proof was too strong to admit of question. He saw, with the aid of his microscope, in a small transparent insect, blood leave the heart, circulate through the limbs, wings and antennæ, then return to its starting point, thus tracing the complete circulation. His results were published in the year 1827, and were soon confirmed by other naturalists.

In studying this subject in the Nepidæ, I have imprisoned larvæ of Belostoma, Perthostoma and Ranatra in flat glass boxes, and, with the microscope, have studied the heart, and traced the circulation through the transparent integument.

The *heart* here described is from dissections of Belostoma. It consists of a long tube extending from the sixth abdominal segment to the supra-œsophageal ganglion. In the abdomen, it is divided into chambers, and this abdominal portion is considered the heart proper, and the anterior tubular portion, the aorta. There are five chambers in the abdomen of the adult, with afferent openings on each side, called by some auriculo-ventricular apertures. At the beginning of the sixth abdominal segment, the heart is attached to the integument by means of muscles. (Fig. 4.)

The first pair of afferent openings are thus thrown into the fifth abdominal segment, and the three following segments have one pair each, making a total of four pairs. These openings are guarded by valves, the action of which will be considered later. These apertures are all anterior to the middle of the body segment in which they are situated. In the larvæ of Belostoma, I have often observed one of these auriculo-ventricular openings in the sixth abdominal segment, and muscular attachments behind it in the anal prolongation. It is my belief that this additional chamber is dropped in the adult form, since I find it in none of my dissections. It is a matter of great difficulty to be sure, whether one of these chambers may not have escaped notice. According to my observations, however, there are five chambers in the adult Belostoma and six in the larva. At the junction of the thorax and the abdomen, the heart bends downward as it extends forward, passing under the large muscles of the thorax.

The triangular Muscles of the Heart.—The heart is attached to the integument in the abdomen, by a number of triangular muscles with their apices pointing outward. I have counted eight pairs of these attachments in the adult Belostoma. They are situated opposite each auriculo-ventricular orifice, and continue both anteriorly, and posteriorly, beyond these openings. At the apex the fibers composing the triangular muscles are closely united into a sort of ligament. These fibers diverge laterally as they approach the heart, and also divide into two sheets, one passing above and the other below the heart. Thus a triangular cavity is left on each side of the heart, which is called the *pericardial* *sinus*. According to Milne-Edwards this has some claims to be considered the auricle of the heart, since its muscles help force the blood through the afferent openings into the heart. In addition to the triangular muscles, the heart is attached in the thorax by a single triangular piece of connective tissue.

The heart beats rhythmically, its activity depending greatly upon whether the insect is quiet or excited. As near as I could conclude, the normal number of beats in Belostoma larvæ is about forty-five per minute. In those confined in glass boxes the number of beats were from thirty-four, to sixty-three, per minute.

The contraction of the different chambers is not quite synchronous; the back chamber contracts first, then the others follow in quick succession, so that the blood is kept constantly moving forwards. At the beginning of the diastole of the heart, the valves guarding the afferent openings bend inward with a quick, almost jerking motion, and permit the entrance of blood from the pericardial sinus; upon the systole of the heart the pericardial sinus receives an accession of blood from the chambers leading to it; the closing of the valves of the afferent openings prevents the return of blood from the heart to this cavity. It has been determined by the investigations of Dogiel, and others, that the heart is kept beating by ganglionic corpuscles, like the heart in vertebrates.

The course of the blood is forward in the heart to the nervous ganglia of the head, where the aorta ends in a funnel-like expansion. From here the blood is thrown into the lacunæ, which are regular channels leading through the connective tissue and among the organs of the body. Although there are no true arteries and veins, the course of the blood is regular through the lacunæ, and the heart may be easily injected by throwing fluid into the body cavity. I have often injected the heart of the Nepidæ by throwing carmine into the ventral cavity. The blood passes into the legs, wings, antennæ, etc., and comes back to join two large currents passing backward along each side of the body; ultimately it gets back to the pericardial sinus, from thence into the heart to begin its course anew.

The Pulsatile Organs of the Legs.—Accessory to the circulation is a special system of pulsatile organs, found in the three pairs of legs of these insects, generally situated in the tibia just below its articulation with the femur. In the raptorial legs of Ranatra, however, the organs are in the clasp joint, or tarsus, below its articulation with the tibia.

PLATE X.

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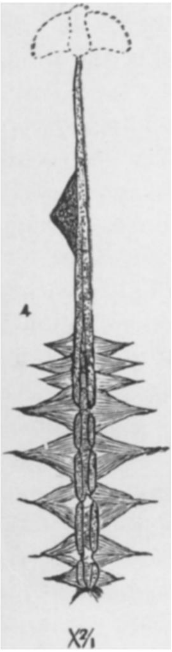
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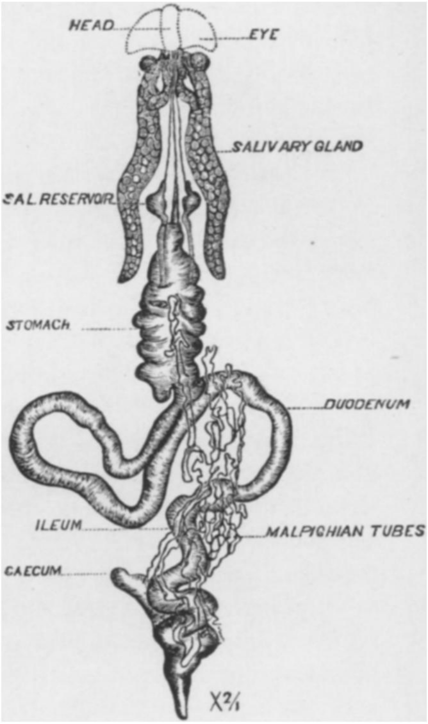
HEAD
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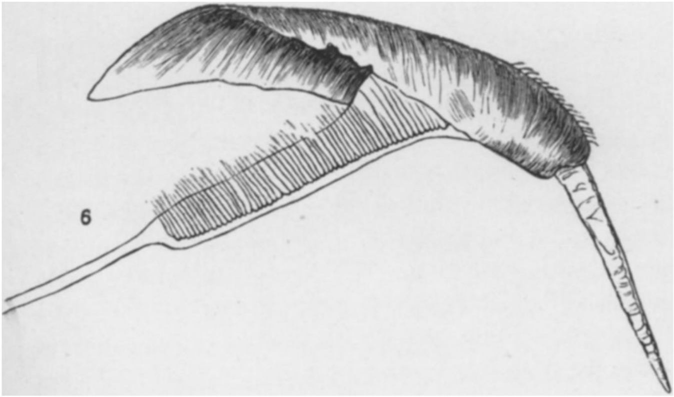

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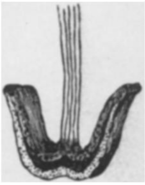


Observations on their influence over the circulation, etc., will be found in the January number, 1884, of the AMERICAN NATURALIST, where my investigations and results are given, that lead to the three following conclusions on these organs: (1) They are separate from the muscular system of the legs; (2) they influence circulation; (3) they are automatic.

III. THE RESPIRATORY SYSTEM.

Connected with the respiratory system of the Nepidæ there is a breathing apparatus, which is peculiar to this family of insects. This characteristic consists of an anal *respiratory siphon* formed by the apposition of the grooved faces of the caudal setæ. Some aquatic larvæ have an analogous, though differently constructed breathing tube, which always disappears in the adult. The caudal setæ of Belostoma and Perthostoma are comparatively short, but in Ranatra are conspicuous for their length. In breathing, these insects rise to the surface and thrust their respiratory siphon out of the water. At the bottom of this tube are two anal stigmata opening into the two main lateral trunks of the respiratory system. In the adult insect,the anal stigmata are the only open ones in the whole abdomen. In addition to these Nepa and Ranatra have, on the ventral surface of each of the third, fourth and fifth abdominal segment, two prominent stigmata, which are closed by a sieve-like membrane and, according to Gerstaecker, perform the functions of tracheary gills.

In the adult Belostoma, the abdominal stigmata are so nearly obliterated that often their scars can be scarcely found with a lens; but the case is strikingly different in the larval forms, which have six prominent stigmata on the last five ventral segments. The last abdominal segment bears two pairs, and each of the four following, one pair each. I noticed in some cases, a spot on the membrane between the first abdominal segment and the mesothorax, which is, perhaps, an additional stigmata, though the work on this point is not very definite. The stigmata show a vestibule on cross section, and lie in a hairy track with their openings guarded by hairs.

The chief external differences between the abdomen of the larva and of the adult Belostoma may be summed up as follows:

Larva.—The ventral surface is covered with rather coarse hairs, the dorsal surface smooth, the stigmata prominent and all open, the sixth abdominal segment comparatively small, and the caudal setæ undeveloped.

Adult.—The ventral surface is smooth, the dorsal surface pubescent, the stigmata totally obliterated, and the caudal setæ developed.

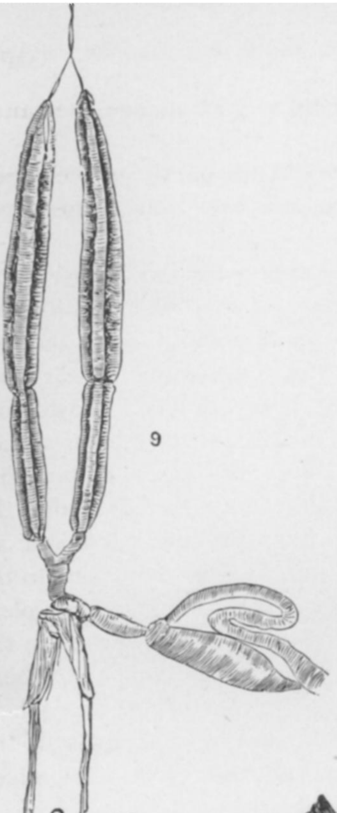
The tracheary branches are distributed to all the organs of the body, so that the chemical processes of respiration are effected throughout the body instead of at special points. From the anal stigmata, two main trunks extend along the abdomen on each side of the heart, giving off and receiving branches which anastomose among themselves. The large trunks are connected by an arcade of tubes running below the intestines. In the larva, branches from the spiracles join the main trunks, and in the adult, after the obliteration of the spiracles, these branches are still found attached to the integument. The distribution of tracheæ to the muscles and organs of the forward part of the body, is very plentiful; large branches extend into the legs and wings; in the mesothorax the nervous ganglion rests on a triangle of tracheæ. Here, too, connected with the trachea, are several air sacs, which are inflated before flight. The dorsal and ventral walls of the abdomen are connected by two vertical rows of muscles, which are doubtless concerned in respiration.

Three kinds of tracheæ are found in these insects: tubular, vesicular and parenchymatous. All the main trunks and branches of the respiratory system are composed of tubular trachea; this, as shown by Minot, consists of an external nucleated epithelium with two internal layers, in one of which is found the spiral thread that keeps the tube open. This spiral filament is not continuous, but separate in each branch, and consists of numerous parallel pieces, each of which tapers to a point after a few turns and thus is lost. The vesicular trachea of the air sacs chiefly differs from the tubular trachea, in lacking the spiral thread. I have made no study of the parenchymatous trachea noted by Dufour as occurring in Nepa. It consists, according to this author, of several pouches covered by a fine, satin-like envelope, within which, minute tracheary branches are matted. These pouches are situated in the thorax under the Scutellum.

B. THE FUNCTION OF REPRODUCTION.

The function of reproduction, which includes generation and development, is here confined to generation. As in the Verte-

PLATE XI.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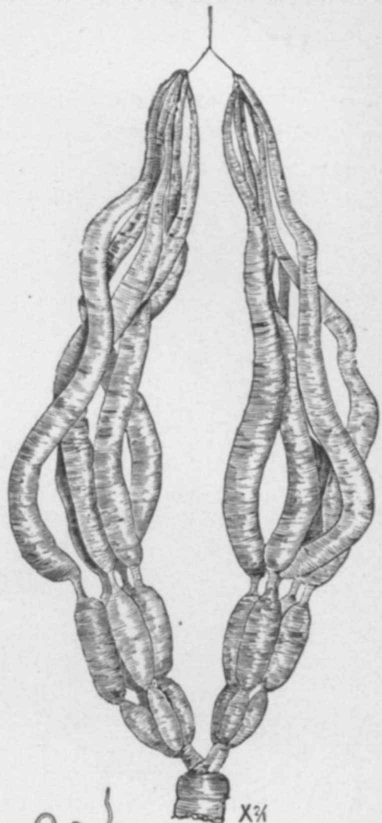
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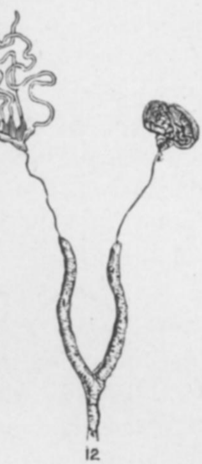
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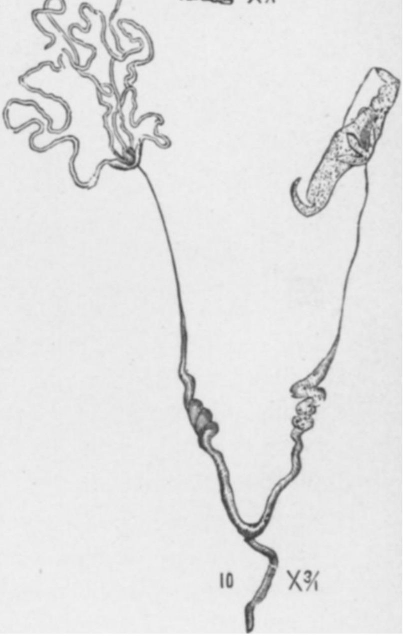
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brata so in the Insecta, two kinds of organs are concerned in this process, the mutual action of whose products upon each other, is usually necessary for the formation of new individuals. These organs are the male organs or testes, producing spermatozoa, and the female organs or ovaries, producing eggs.

I. THE MALE GENERATIVE SYSTEM.

The testes of the male Belostoma lie in the anterior portion of the abdominal cavity, on each side of the pyloric end of the stomach. They consist of a rounded body, which in reality is a membranous sac, mounted on a sort of receptacle composed of five pieces closely packed together. From each of these five pieces, arise spermiferous tubes which are much matted in the membranous sac. (Fig. 12.) The vas deferens, which leads backward from the testes, is thread-like for the first half of its course, and then enlarges into a tube, which joins with the one from the opposite side to form the ductus ejaculatorius, which conducts the spermatic fluid to the organ of intromission. (Fig. 11.) This is formed by two pieces, a pick-shaped structure above and a spoon-shaped one below it; both organs are situated on the genito-anal prolongation, which corresponds to a dorsal and ventral part of a seventh abdominal segment. The prolongation is provided with copulatory hooks, which in the female are rudimentary.

In Ranatra, the general arrangement of the generative apparatus is the same, though in detail, somewhat different. The spermiferous tubules are confined in an elongated sac, which is much farther forward than in Belostoma, and the vas deferens, after enlarging, is coiled several times upon itself before passing into the ductus ejaculatorius (Fig. 10.) The coils are compact and form a lenticular enlargement on the vas deferens, sometimes mistaken for the testes.

II. THE FEMALE GENERATIVE SYSTEM.

The ovaries of the female consists of two series of five tubes each, one on either side of the body. These terminate in the thorax, where their small pointed ends are joined together by connecting threads, which serve also to attach them in the thorax. Proceeding outward they gradually grow larger until they all meet at the calices, the tubes of which unite to form the vagina or oviduct. These organs vary greatly in size according to the season, sometimes quite contracted, and sometimes so distended with eggs as to fill nearly the whole abdominal cavity. The tubes of the ovaries double upon themselves in the first segment of the abdomen, the flexure reaching back nearly to the third segment. (Fig. 14 *a.*)

As already noted, the females of Perthostoma carry their eggs upon their backs until hatched, the young then escaping by means of a trap door at the top of the egg. The number of eggs borne by any insect is variable; I counted them in four individuals with the following results: 207, 185, 184, 183, and other females were dredged bearing less than half as many. The eggs of Ranatra and Nepa are crowned with setæ, two on the eggs of Ranatra and six on those of Nepa, while the eggs of Belostoma and Perthostoma have none.

The female generative organs of Ranatra lack the flexure that occurs in those of Belostoma, but in other respects are quite similar. Their chief differences may be seen on reference to Figs. 8 and 9, Plate XI, which are drawn on the same scale.

C. THE FUNCTION OF RELATION.

To secure a just harmony in the activity of the different organs of the body, a combining organ of some kind is necessary. The food must be adequate to meet the waste of the body. Intelligence to know when food is needed, and to discriminate between nutritious and innutritious food is essential; respiration must be regulated to supply enough oxygen, but not too much. These and all other processes of animal life must be brought into relation with each other, otherwise the organs would be useless. This round of duties, which is performed by the nervous system and the muscles, over which it has control, constitutes the function of relation. In some respects it is the most important function, since it directs all the others.

I. THE NERVOUS SYSTEM.

The insects of this family are keen and shrewd in detecting their prey, and energetic in procuring it, hence their general nervous condition must be an active one. They show a considerable degree of cephalization, all the abdominal ganglia have advanced to the mesothorax, where they unite with others to form a complex thoracic ganglion. The remaining ganglia form two conglomerate masses, one below the œsophagus, called the infra-œsophageal ganglion, and the other above, called the supra-œsophageal ganglion, sometimes considered the brain. This brain consists of two " cerebral lobes " slightly overlapping, and sending two large commissures around the œsophagus to the infra-œsophageal ganglion. The optic lobes, which are somewhat pear-shaped, extend obliquely from the summit of the " cerebral lobes " toward the eyes, and give rise to the numerous fibers of the optic nerves.

The cerebral ganglia send nerves to the antennæ, and also send a small branch to the frontal ganglion. This ganglion is a small knot of nervous matter situated on the median line of the head, just in front of the cerebral ganglia. The frontal ganglion supplies the œsophagus anteriorly, with nerve filaments and posteriorly, by filaments from a main branch extending backward underneath the " cerebral lobes." " The respiratory ganglia," which I did not find, are described by Dr. Leidy as " two small ganglia behind the brain, on each side of the œsophagus and connected with each other and with the 'cerebrum' by exceedingly delicate commissural filaments." From each side of the infra-œsophageal ganglion a bunch of nerves originates, which sends branches to the muscles and the organs of the prothorax, and to the anterior legs.

A double commissure connects the infra-œsophageal ganglion with the complex ganglion of the mesothorax. The latter gives off branches anteriorly, laterally and posteriorly. The anterior branches partly supply the prothorax; the lateral branches supply mainly the organs and muscles of the meso- and metathorax and the posterior legs; and the posterior branches, the muscles and organs of the abdomen (Fig. 17).

II. Organs of Special Sense.

Although there is good evidence of the existence of the special senses among insects, considerable speculation exists concerning the location of all, except the sense of sight.

Touch.—In these insects the sense of touch through the integument must be very blunt, and the real organs of this sense probably are the tactile hairs found on different parts of the body. These hairs communicate with the terminations of the nerve fibers beneath the integument. I have often been impressed with the idea, that the tufts of hair found at the extremity of the beak, in all the Nepidæ, are especial organs to give it a delicate sense of touch.

Taste and Smell.—The work on these insects as far as carried out, furnishes no suggestion as to the location of the senses of taste and smell, and, as far as my knowledge goes, their existence rests wholly on analogy. In some insects, as the Silphidæ, smell is obviously present and directs them to their food; and taste is probable in insects possessing soft tongues.

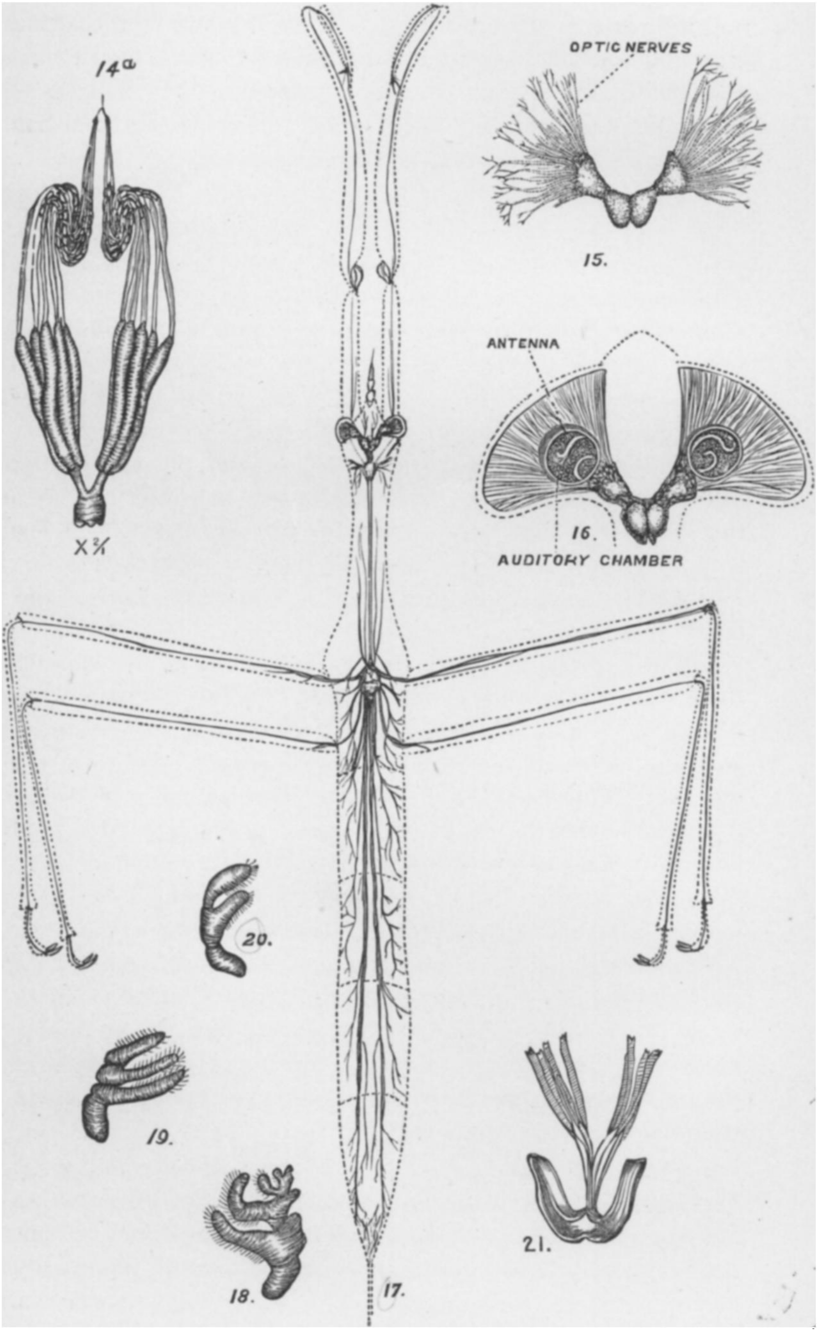
Hearing.—Hearing in the Insecta is usually located by anatomists in the antennæ. This is made very probable by investigations similar to those of Mayer, the physicist, on the mosquito. This observer, by watching through the microscope the hairs on a mosquito's antenna, found that they responded by vibrations to certain sounds that he produced; the hairs, being of different lengths, responded to several sets of vibrations, but always strongest to the note emitted by the female mosquito.

Other experiments of a similar nature, and the fact that some insects appear deaf when the antennæ are removed, add force to the conclusion that they serve as organs of hearing. A few insects, the Orthoptera, for instance, have special organs for the reception of sound, either on the thorax or at the base of the anterior legs.

In the Nepidæ, there are certain conditions in the situation of the antennæ that seem to me favorable for the increase of sound vibrations. The Belostoma and Perthostoma have each of the antennæ enclosed in a vaulted cavity, which is suggestive of a resonance chamber. Each chamber extends into the eye above it, and separates the fibers of the optic nerve into two bundles; and its opening below the eye is partly closed, so that a cleft is left toward the median line of the head, through which the antennæ may be protruded or withdrawn. The antennæ are well provided with sensitive hairs (Fig. 18), which doubtless respond to the sound vibrations received in the auditory chamber. In cross-section the auditory chamber presents a view shown in Fig. 16, Plate XII. The Ranatra emits a squeaking sound by working the front legs up and down on the joint at the coxæ, where the roughened surfaces come together.

Sight.—The Nepidæ have two prominent compound eyes, one on each side of the head, but no ocelli. They are covered externally by a modification of the integument, which answers to the cornea of the vertebrate eye. This is divided into a great number of hexagonal facets, underneath each of which is found a crystalline

PLATE XII.


14a
X 2/1
OPTIC NERVES
15.
ANTENNA
16.
AUDITORY CHAMBER
20.
19.
18.
17.
21.

cone with the apex directed backward. The filaments of the optic nerve are branched at their extremities (Fig. 15); each of these branches probably enters a cone. The theory of mosaic vision is so generally discussed that no repetition of it is needed here.

III. THE MUSCULAR SYSTEM.

To bring an animal into true harmony with its surroundings, muscles are necessary to move the body from place to place, so that the animal may court agreeable, or favorable conditions, and shun disagreeable, or unfavorable conditions.

No special study of the muscular system of the Nepidæ has been made, but a few points that incidentally appeared during dissection are mentioned.

The most striking mass of muscular tissue is in the meta- and mesothorax, the muscles of which are mainly concerned in flight and in moving the limbs. The muscles of the legs are well developed, and may be studied through the integument if it is scraped thin. The elevators and depressors of the beak, and the muscles of the beak bristles, are easily demonstrated in the head and in the prothorax. The respiratory muscles of the abdomen, and the muscles of the pharynx, have already been described. In many cases special provisions for the attachment of muscles are provided by means of chitinous processes and chitinous threads. The latter are very conspicuous in the prothorax of Ranatra and in the retractor muscles of the setæ. The chitinous processes are found plentifully in the meso- and metathorax, and two prominent ones are borne on the back of the head.

Conclusion.—Even in this cursory view of the family Nepidæ, the adaptation of organism to function is often too obvious to escape notice. The influence of food and surroundings, the two most important factors in modifying structure, is seen producing great similarity of internal organs, under variable external form. The adaptive characters are also very apparent in the raptorial fore-legs, the beak, the sucking pharynx, the respiratory siphon and in many other structures. The general principles of their physiology is the same as that of the vertebrates. There is the same conflict between waste and repair, the identical processes of changing food into muscle and nerve, the same general chemistry of respiration, etc., etc. They are not endowed with mind, but possess sufficient nervous sense to meet their requirements, and, although built on a simpler plan, are as distinctly physiological machines as are all vertebrates.

DESCRIPTION OF PLATES IX, X, XI, XII.

FIG. 1.—Head of Belostoma larva seen from above, dissected so as to show the cephalic glands. In front is seen the beak with the sheath and bristles withdrawn, and the bristles pushed to the left.

FIG. 2.—Side view of beak and portion of head of Perthostoma, with pumping apparatus and one cephalic gland attached. In this case the sheath extends into the beak, as is natural. The bristles are not shown.

FIG. 2 *a*.—View from above of the cephalic gland of adult Belostoma, × about 20 diameters.

FIG. 3.—Digestive apparatus of Ranatra ($\times\frac{3}{1}$). The Malpighian tubes are represented in part only, portions having been removed in dissecting.

FIG. 4.—Heart of adult Belostoma (× 2), showing triangular muscles, the different chambers of the heart and the afferent openings. Some of the muscular fibers should be represented as crossing above the heart. Anterior to the muscles on the left is seen the triangular attachment of connective tissue.

FIG. 5.—Digestive apparatus of Belostoma (× 2). The salivary glands and the ilium are represented as *too wide*. Part of the Malpighian tubes were removed before the drawing was made.

FIG. 6.—Portion of the head of Belostoma with the sheath and the pumping apparatus attached (magnified at least twenty diameters). The œsophagus enters the pumping apparatus from the left. The oblique lines represent the chitinous threads for muscular attachments.

FIG. 7.—Cross-section of the pumping apparatus (magnified as above).

FIG. 8.—Female generative apparatus, extended and spread, from a large specimen of Belostoma (× 2). Compare with Fig. 14 *a*.

FIG. 9.—Female generative apparatus of Ranatra (× 3). Three tubes of each ovary in sight. Below is seen the cæcum and a part of the intestine pushed to the right.

FIG. 10.—Male generative apparatus of Ranatra (× 3). On the right is seen the elongated sac in which the spermiferous tubes are matted; on the left the sac is removed and the tubes spread out. The vas deferens, at first thread-like, enlarges and coils upon itself several times before emptying into the ductus ejaculatorius.

FIG. 11.—Male organ of intromission, Belostoma, considerably enlarged. Drawn with the camera lucida.

FIG. 12.—Male generative apparatus of Belostoma (× 2). Membranous sac rounded, thin, showing tubes within; on the left the sac is removed and the tubes spread as in Fig. 10. Vas deferens not coiled.

FIG. 13.—Side view of genito-anal prolongation, one seta removed, and the penis elevated to the right. On the side of the genital prolongation is seen the copulatory hook.

FIG. 14.—Genito-anal prolongation and caudal setæ, front view.

FIG. 14 *a*.—Female generative apparatus of Belostoma ($\times \frac{2}{1}$), showing the flexure of the ovaries and immature ova in their upper part.

FIG. 15.—Portion of brain and optic nerves of Belostoma, to show the branching at the extremities of the optic nerves.

FIG. 16.—Cross-section of head of Belostoma from above, to show the auditory chambers and parts of the enclosed antennæ.

FIG. 17. Nervous system of Ranatra ($\times \frac{3}{1}$). The branching of the nerves in the abdomen partly diagrammatic.

FIG. 18.—Antennæ of Belostoma.

FIG. 19.—Antennæ of Perthostoma.

FIG. 20.—Antennæ of Ranatra. The last three figures from camera lucida sketches.

FIG. 21.—Cross-section of pumping apparatus, showing how the muscles are attached to the chitinous threads, and how they divide into two sheets as they pass upwards.

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TOPOGRAPHICAL PHENOMENA IN INDIANA.

BY JOHN T. CAMPBELL.

ABOUT fifteen years ago I was engaged in helping to make several surveys in Western Indiana and Eastern Illinois for railroad purposes. In such work one is apt to notice topography sharply. While thus employed I observed that the hills along all the east-west flowing streams on the up or table-lands were steep and abrupt facing northward, and on the opposite side, facing southward, they were gentle slopes. This was true throughout the glacial drift region. As the streams in nearing the Wabash river wore down below the drift, the slopes reversed, and the steepest hills faced the south, but the difference in slope is not nearly so noticeable as the opposite in the drift.

At the time I first observed this peculiarity of slope, I had read no work on geology, and had but a very limited idea of dynamical geology, derived from a meager recollection of a few lectures on the subject, heard several years before. I supposed these phenomena were not only observed and described, but accounted for. In my subsequent reading on the subjects which ought to cover this, I have been not a little surprised to find that these *facts* have not only *not* been accounted for, but not *observed.* After my failure to find it where I expected, I inquired of men eminent for their knowledge of such subjects as should include this, and have found that not one out of nine seemed to have observed or heard of the phenomena, and several even expressed a doubt of the existence of the facts.

During my subsequent readings and inquiries, I have greatly